Therenewal of th old economy

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The Renewal of the Old Economy: Europe in an Internationally Comparative Perspective

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Abstract:
This paper deals with international comparisons of the contribution of information and communication technology (ICT) to growth during the 1990s. It makes a distinction between ICT-producing industries and services on the one hand and industries and services that are intensive users of ICT on the other. The paper presents measures of output and employment shares and of the contribution of the ICT-producing and ICT-using sectors to output, employment and labour productivity growth. The main findings are that the differences between the United States and European countries are largely explained by the larger and more productive ICT-producing industry in the United States. The differences in the contribution of ICT using industries and services to growth are much smaller and more subtle between Europe and the USA. The paper also reviews recent evidence on ICT investment and capital. It appears that the growth contribution of ICT-use increased during the second half of the 1990s, but so far the effects are visible only in the United States. It also argued that many European countries have so far not succeeded to generate positive employment effects from intensive ICT-use.

1. Introduction

The recent increase in the share of information and communication technology (ICT) in production and investment has been dubbed by many as the main vehicle by which the slowdown in economic growth in the western world may be called to a halt. The empirical support for this viewpoint, however, comes mainly from the US experience. During the 1990s there has been a clear acceleration of growth in the American economy. For example, between 1995 and 1999, labour productivity growth in the US was about 2.25% per annum, and employment rose by 1.6% per year. Some argue that the growth acceleration is mainly due to improved productivity growth in the ICT-producing sector (Jorgenson and Stiroh, 2000). Others also stress the increasingly productive use of ICT-goods and services elsewhere in the economy (Oliner and Sichel, 2000). However, there are also critics who argue that ICT does not have the potential to raise growth like earlier innovations during the twentieth century, such as the introduction of electricity, the combustion engine, etc. (Gordon, 2000).[2]

To study the effect of ICT on economic growth in Europe is even more complicated than for the United States. During the 1990s trend growth of GDP in the European Union was one percentage point below that of the United States. Labour productivity growth was also behind in particular during the second half of the 1990s. Moreover the diversity in growth performance across European countries increased. The causes of this diversity are multifold, ranging from slow growth in investment, rigidities on labour, product and capital markets, sluggish demand and lack of technological progress (Ahn and Hemmings, 2000; Scarpetta *et al.*, 2000; OECD, 2000). A small effect of ICT on growth is therefore only one of many possible explanations for slower growth in Europe. This paper aims to document how much European countries stayed behind the United States in terms of production and use of ICT.

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[2] In addition, Gordon (1999) stresses that part of the growth acceleration in the United States is due to the pro-cyclical productivity effect in the upward phase of the business cycle.

To analyse the extent to which ICT accounts for growth differences between Europe and the United States, the shares of ICT producing industries in output, labour input, investment need to be determined first. Section 2 shows that even though the importance of ICT producing industries in the economy have steadily increased, these are still quite low in all countries, including the United States. However, ICT producers accounted for a fair share of growth during the second half of the 1990s. In particular ICT-manufacturers, i.e. producers of computer hardware and accessories, have strongly contributed to output growth in the United States, whereas the differences between countries are smaller for ICT-producing services (section 3).

Much of this paper deals with the degree to which ICT use leads to productivity growth in the rest of the economy – in popular terms sometimes called the "old economy". Earlier studies on the introduction of electricity at the beginning of the previous century, showed that it was not so much electricity production itself but the use of electricity elsewhere in the economy that supported a long term growth acceleration (David and Wright, 1999). In other words, it is the successful diffusion of ICT that brings the economy onto a higher growth path.[3] Section 2 therefore makes a distinction between industries that make intensive use of ICT and sectors which invest relatively little in ICT. This shows that the differences in output shares of intensive ICT users between European countries and the US are not as big as for ICT producers. But Section 3 shows that the United States has not only been more successful in generating faster output growth in ICT-using sectors but also in creating more employment in these industries. A shift-share analysis also suggests a high contribution of ICT-using sectors to labour productivity growth in the United States. For European countries I observe large differences in productivity and employment generating effects from ICT. For example, whereas the ICT-using sector in Germany contributes substantially to productivity growth, the employment generating effects are limited. In contrast, the ICT-using sector in the Netherlands accounts for a large part of employment generation in the Netherlands, but productivity growth is less than in Germany though faster than in Denmark or France.

The complicated issue of measurement problems in production, inputs and productivity cuts right through this accounting exercise. This partly involves the measurement of the ICT producing sector itself, including computer-hardware, computer services, audio- and videoequipment and telecommunication. But equally important are the problems of measuring the inputs and output of industries that intensively use ICT, in particular in services, which include the financial sector, business services, etc.. Measurement problems have increased partly because of the greater importance of service industries for which output has always been difficult to measure (Baily and Gordon, 1988; Griliches, 1994; Sichel, 1997; Van Ark, 2000a). Moreover, measurement problems may have further increased because of new products and services within these industries which are more difficult to measure. Indeed the greater use of ICT may have contributed to these problems, as ICT strongly supporting customization of products and services (Diewert and Fox, 1999; Lehr and Lichtenberg, 1999; McGuckin and Stiroh, 1999). In section 4 I will take a systematic look at which sectors of the economy generate the largest measurement errors.

[3] From the perspective of international trade one might argue that specialization in a high-tech sector like ICT might generate permanent growth effects compared to countries that are less specialised in ICT production. Much depends, however, on how ICT is exploited as a general purpose technology generating important technological changes elsewhere in the economy. See also the concluding section.

Finally, in Section 5 the results on the role of ICT in the economy from this study will be compared with those from earlier studies. Because of lack of data there have been no internationally comparisons at the sectoral level, but the facts from more aggregated studies (Schreyer, 2000; Daveri, 2000) as well as from separate work on the US (Oliner and Sichel, 2000; Jorgenson and Stiroh, 2000) and the Netherlands (CPB, 2000b) largely coincide with the results in this paper. Some European countries follow the US pattern of a rising contribution of ICT capital to growth quite closely in terms, whereas others are still at a greater distance.

The dataset for this study is based on the new (and as yet unpublished) STAN dataset of the OECD. At some places the STAN database, which has a breakdown of 43 industries based on the ISIC rev. 3 classification, is not detailed enough to exactly cover the ICT-sector. Further refinements were made using information from production statistics and national accounts for individual countries.[4] Appendix B describes the database in some more detail. A more extensive description of the data and the series for the ICT-producing and ICT-using sectors from 1990 onwards will be made available through the website of the Groningen Growth and Development Centre (http://www.eco.rug.nl/ggdc). The detailed comparisons in this study are for Denmark, Germany, France, Italy, the Netherlands and the United States. In the future the database will be extended to other countries.

2. The share of ICT in the economy

Expenditures on ICT

The use of information and communication technology has rapidly increased during the past two decades. Information on the expenditure on ICT goods and services can be obtained relatively easily. The left hand part of Table 1 provides an overview of expenditure on ICT, first as a percentage of the Gross Domestic Product in various countries and, second, as a percentage of the US expenditures per head of the population. It shows a substantive diversity across Europe. Notably the Scandinavian countries, the Netherlands and the UK score relatively well. The right hand part of the table shows the number of personal computers (PCs) and mobile phones per 100 persons and the number of PCs and internet connections per 100 households. Again some European countries score well. On mobile phones the Scandinavian countries even score much better than the United States.

The relation between ICT expenditure and economic growth is complicated because a large share of expenditure is consumption. For example, Daveri (2000) shows that only 65 per cent of US expenditures on computer hardware can be counted as investment. The data on expenditures on software, however, are an understatement of investment because in-house software production is not included in the data. Schreyer (2000) treats only 30 per cent of expenditure on telecommunication as investment. Another aspect of the rise in ICT expenditure is that it partly involves substitution for existing activities, for example in the case of e-commerce. Even though e-commerce might create new economic activities in the long run, it reflects at least partly a substitution for existing shopping behaviour. Despite the increased importance of e-commerce, the effect on economic growth is difficult to quantify (Coppel, 2000).

[4] See Appendix A for definitions of ICT-producing sectors and industries characterised as intensive ICT users in the basis of the ISIC rev. 3 classification.

It is therefore necessary to develop alternative approaches to assess the role of ICT in the economy. Firstly one can compare industry shares of ICT in production, employment and investment. Secondly one can compute the contribution of these industries to the growth of Gross Domestic Product and productivity. The second approach is part of Section 3. Below the focus is on the shares of ICT producing industries and of industries that are characterized as heavy ICT users.

Table 1: Expenditure on and Use of Information and Communication Technology, 1997

	ICT	Expenditure per person as % of USA				per 100 persons		per household	
	Expen-diture as % of GDP	Tele-commu-nication	IT Hardware	IT Software	IT Services	PC's	Mobile phone (a)	PCs (b)	Internet (b)
Netherlands	7.0	53.5	57.8	71.7	40.5	30.0	10.8	65.0	22.0
Austria	5.1	42.9	45.2	43.1	40.0	20.0	14.3		
Belgium	6.0	46.8	46.2	64.0	39.7	16.0	9.6		
Denmark	6.5	72.7	76.8	61.2	72.9	34.0	27.5	52.0	31.0
Finland	6.0	51.0	60.5	40.3	44.9	29.0	45.6	49.0	28.0
France	6.4	48.3	39.0	47.7	58.8	18.0	9.8	35.0	16.0
Germany	5.6	45.1	46.1	49.6	41.9	22.0	9.9	48.0	16.0
Greece	4.0	7.2	8.5	5.6	6.3	5.0	8.6		
Ireland	5.7	27.2	32.7	24.0	22.3	16.0	14.4		
Italy	4.3	24.2	21.3	27.1	26.1	10.0	20.5		
Portugal	5.0	10.0	12.6	7.9	7.9	8.0	15.4		
Spain	4.1	15.0	17.7	13.1	13.0	8.0	10.9		
Sweden	8.3	78.0	82.6	52.4	83.9	35.0	35.8	58.0	42.0
United Kingdom	7.6	60.6	64.2	73.7	50.7	23.0	14.3	41.0	16.0
Average EU (c)	5.9	41.6	43.7	41.5	39.2	19.6	17.7	49.7	24.4
United States	7.8	100.0	100.0	100.0	100.0	50.0	20.4	58.0	42.0
Japan	7.4	65.3	72.3	41.2	67.8	20.0	30.4		

(a) 1998; (b) early 1999; (c) unweighted averages, except for expenditure/GDP shares
Sources: OECD (1999, 2000) and data from International Data Corporation

Output and Employment Shares of ICT Producing Sector

The precise shares of ICT in total output and employment depend on the definition of ICT industries.[5] Table 2 shows the change in shares of ICT producing industries in value added (in current and constant prices) and in employment. ICT producing industries consist of IT hardware, radio, television and communication equipment, medical appliances and instruments and appliances for measurement (together the ICT industry) and telecommunication and computer services (together ICT services). This definition of ICT-producing industries matches the classification used by the OECD.[6]

[5] Even when ICT industries are defined, the point remains whether one counts the value of all products and services in those industries or only that of ICT products and services. Moreover, ICT products and services can also be produced in industries which are not defined as such.

[6] See also the top panel of Appendix Table 1. The difference with the OECD classification is that wholesale trade in machinery and equipment and the renting of ICT goods is not included due to lack of data (OECD, 2000c). It also appeared not possible to separate postal services from telecommunications.

Above all table 2 shows that the shares of ICT producing industries in total GDP and employment are strikingly low. Even for the United States, which has the highest shares for all indicators, the percentage shares for the total economy are less than 10 per cent. Secondly the shares of ICT producing industries are generally higher for GDP than for employment, which suggests higher productivity levels in ICT industry and services compared to the rest of the economy.

Table 2: GDP and Employment Shares of ICT-producing industries, 1990 and 1998

	ICT industry as % of total manufacturing		ICT services as % of total business services		ICT as % of total economy	
	1990	1998	1990	1998	1990	1998
	as % of GDP at current basic prices					
Netherlands	9.2	7.8	6.3	7.9	4.6	5.4
Denmark	6.0	7.0	7.4	7.8	4.3	4.7
France	7.4	7.4	7.4	8.1	5.0	5.3
Germany	7.8	6.4	7.8	7.9	5.4	5.1
Italy	5.7	4.8	6.8	7.5	4.4	4.7
United States	13.2	15.7	9.1	9.7	6.6	7.6
	as % of GDP at constant basic prices					
Netherlands	8.1	8.3	6.5	8.6	4.5	5.8
Denmark	5.5	7.2	5.8	7.9	3.6	4.8
France	5.9	10.3	6.8	8.6	4.3	6.1
Germany	6.9	6.6	7.3	8.6	4.9	5.4
Italy	5.7	4.8	6.8	7.5	4.4	4.7
United States	10.7	20.4	8.7	9.7	5.9	8.6
	as % of employment					
Netherlands	8.9	7.4	5.3	6.1	3.6	3.7
Denmark	6.2	6.1	8.3	7.3	4.1	3.7
France	6.2	6.2	7.0	6.9	3.8	3.7
Germany	7.8	6.3	7.3	6.1	4.6	3.6
Italy	3.8	3.8	7.8	7.5	3.6	3.6
United States	11.6	11.6	6.2	6.9	4.5	4.7

(a) For Germany for 1991 and 1997
Source: ICT database (see appendix B).

Table 2 also shows some important differences between countries. For example, for the European countries the share of ICT producing industries in nominal output remained constant or even declined between 1990 and 1998. In contrast, it further increased in the United States. In real terms it even double from 10.7 per cent to 20.4 per cent of total GDP in the US.[7] The share of Danish and French ICT industries in real value added increased as well. This suggests a difference in measurement method between countries: Denmark, France and the United States use hedonic price indexes for computers whereas Germany, Italy and the Netherlands do not. The hedonic price indices show a significantly faster decline of computer prices than traditional price indices (see Section 4 for a more extensive discussion). For ICT producing services the output shares increased in all countries, but the employment shares declined except for the Netherlands and the United States.

Output and Employment Shares of ICT Using Sector

The question on how much ICT contributes to economic growth requires a focus not just on ICT production, but also on how much the increased use of ICT contributed to output and productivity growth. Two remarks should be made on the definition of industries marked as heavy ICT users. Firstly, a distinction between heavy and less intensive ICT users is necessarily arbitrary. There are few industries that do not use ICT at all. Secondly, in my definition ICT producing industries are part of heavy ICT users. The criteria to distinguish between heavy ICT users and light uses are ICT intensity, i.e., the share of ICT-investment in industry output, and the industry share in the ICT capital stock. About one third of industries with the highest ICT-intensity and/or the highest shares in the ICT capital stock are defined as heavy ICT users. I used data for both the Netherlands and the United States which roughly show the same distribution between heavy and light users (see Appendix Table 1). Heavy users are publishing and printing, the chemical industry, electrical and electronic machinery and equipment, medical and measurement appliances (together ICT using industries), wholesale trade, post and telecommunication, the financial sector, the renting of machinery, computer services, research and development and part of business services (accountants, architectural firms, legal offices, consultants and marketing agencies) (together ICT using services).

Table 3: GDP and Employment Shares of ICT-using industries, 1990 and 1998

	ICT industry as % of total manufacturing		ICT services as % of all services		ICT as % of total economy	
	1990	1998	1990	1998	1990	1998
	as % of GDP at current basic prices					
Netherlands	36.5	34.7	31.4	33.9	27.7	29.9
Denmark	25.9	28.0	26.0	26.0	22.8	23.4
France	26.3	28.1	28.3	27.2	24.6	24.7
Germany	30.0	28.4	30.0	29.0	26.9	26.0
Italy	21.6	21.8	31.9	31.9	25.6	26.4
United States	45.5	44.7	30.8	35.5	29.4	33.3
	as % of GDP at constant basic prices					
Netherlands	35.9	36.8	32.3	35.0	28.5	31.1
Denmark	25.2	30.6	26.0	26.4	23.0	24.0
France	25.1	31.2	27.5	27.2	23.9	25.2
Germany	28.5	29.1	28.6	30.6	25.5	27.1
Italy	21.4	22.4	29.7	32.6	24.4	26.8
United States	32.3	36.8	30.6	34.8	27.3	31.7
	as % of employment					
Netherlands	27.4	25.0	22.9	23.9	21.1	21.5
Denmark	22.2	22.9	22.3	21.5	19.6	19.4
France	21.4	22.0	22.8	21.8	19.3	19.3
Germany	27.0	25.6	21.8	21.5	20.3	19.7
Italy	16.6	16.7	22.9	23.2	17.9	18.8
United States	29.5	29.0	25.7	27.3	23.5	24.7

(a) For Germany for 1991 and 1997; (b) including government, health, education, etc..
Source: ICT database (see appendix B).

[7] The computation of output shares in real terms is not quite correct when chain indices are used, as the output components do not add up to the total. See, for example, Whelan (2000). For relatively short periods such as in this paper the error is quite small, i.e. in the order of 1-2 percentage points.

An important similarity between Tables 2 and 3 is the small increase in the shares of ICT using and ICT producing industries during the 1990s, most of which comes from the rise of ICT using services. Compared to Table 2, Table 3 also shows some major differences. The relative difference in output shares of ICT using sectors between Europe and the United States is smaller than for ICT producing sectors. For the Netherlands the real output share of ICT using services is even bigger than in the United States, whereas the share of ICT using industries is the same as in the USA. The differences are due to different industry composition of the sector. For a small country like the Netherlands, there is a greater degree of specialization, in this case in chemicals, in electrical machinery and equipment and in computer services.

Two important conclusions follow from the analysis so far. Firstly, the share of the ICT producing sector is relatively small in all countries, but the United States is clearly ahead of the European countries. Secondly, the relative differences in output and employment shares between European countries and the United States are much smaller for ICT using industries.

3. The Contribution of ICT to Economic Growth

Despite low shares of the ICT sector in output and employment, the impact on growth may have been bigger than the analysis of the shares suggests. First this section deals with the contribution of the ICT producing sector and the ICT using sector to the growth of GDP and employment between 1990 and 1998. Next I will deal in more detail with the contribution of these sectors to productivity growth.

The Contribution of the ICT Producing Sector to Growth of Output and Employment

Table 4 shows the contribution of the ICT producing sector to the growth of GDP and employment.[8] The contribution of the ICT producing sector ($C_{(t)}$) to the growth of GDP in year (t) ($\Delta KGDP_{(t)}$) can be computed on the basis of the following equation:

$$C_{(t)} = [CICT_{(t-1)} * \Delta KICT_{(t)}] / \Delta KGDP_{(t)}$$

with $CICT_{(t-1)}$ representing the weight expressed as value added in current prices of the ICT-sector in the preceeding year (t-1) and $\Delta KICT_{(t)}$ representing the growth of value added in the ICT sector in the current year (t).[9] The contribution of the ICT sector to employment can be calculated in a similar way.

Table 4 makes a distinction between the average contribution of the ICT sector for the period 1990 to 1998 and for the most recent period 1995-1998. The left handpart of the table shows that the contribution of the ICT producing sector to real output growth is clearly higher for the United States than for the European countries. During the most recent period (1995-1998) the percentage contribution was about 18 per cent of US GDP growth. For Denmark, Italy and the Netherlands the contribution of the ICT producing sector was about 10-15 per cent. The relatively strong growth

[8] Even though an adjustment for hours worked per person would be desirable, this appeared not possible at this level of detail.

[9] The use of annual shifting GDP-weights minimizes the distortion due to deviations of the share in the current year compared to the base year.

contribution of the ICT producing sector to real GDP growth in France since 1995 (about 24 per cent) largely stems from the ICT producing industry. This stronger contribution is at least partly due to the use of hedonic price indices for the deflation of output of personal computers in France.

Table 4: Growth Contribution of ICT-Producing Sectors to Real GDP and Employment Growth

	Real GDP Growth	%-point contribution of ICT producing sector		Employ-ment Growth	%-point contribution of ICT producing sector	
		ICT-industry	ICT-services		ICT-industry	ICT-services
Netherlands						
1990-98	2.50	0.03	0.24	1.46	-0.05	0.10
1995-98	3.43	0.05	0.48	2.60	0.00	0.22
Denmark						
1990-98	1.79	0.05	0.19	0.26	-0.01	-0.03
1995-98	2.34	0.06	0.17	1.54	0.02	0.00
France						
1990-98	1.26	0.12	0.15	0.11	-0.02	0.02
1995-98	1.84	0.20	0.25	0.58	-0.01	0.04
Germany						
1991-97	1.09	-0.03	0.14	-0.64	-0.11	-0.04
1994-97	1.73	0.00	0.24	-0.55	-0.08	-0.09
Italy						
1990-98	1.35	0.02	0.16	-0.21	-0.01	0.00
1995-98	1.46	0.01	0.19	0.37	0.00	0.03
United States						
1990-98	3.15	0.29	0.25	1.48	0.00	0.10
1995-98	4.60	0.47	0.35	2.05	0.04	0.16

Source: ICT database (see appendix B).

The right hand part of table 4 shows the contribution of the ICT producing sector to employment growth. Firstly it should be noted that of the six countries in the table only the Netherlands and the United States have experienced a strong growth in total employment. The contribution of the ICT producing industry to employment growth appears zero or negative during the 1990s, with the exception of the United States. ICT producing services account for about 8 per cent of total employment growth in the Netherlands and the United States, but much less in the other countries.

The Contribution of the ICT Using Sector to Growth of Output and Employment

Using the same methodology as above, the contribution of the ICT using sector to output and employment can be computed as well. As in table 4, table 5 shows the lead of France and the United States in terms of the contribution of the ICT using industry to GDP growth. For France this lead is largely due to the strong contribution of the ICT producing industry, which is part of the ICT using industry. In the case of ICT using services, the Netherlands and the United States lead the other countries.Even after adjusting for the contribution of ICT producing services, ICT using services in these two countries contribute more to the rise in GDP and employment than in the other countries.

Table 5:Growth Contribution of ICT-Using Sectors to Real GDP and Employment Growth

	Real GDP Growth	%-point contribution of ICT using sector		Employ-ment Growth	%-point contribution of ICT using sector	
		Industry	services		industry	services
Netherlands						
1990-98	2.50	0.14	0.90	1.46	-0.10	0.46
1995-98	3.43	0.14	1.61	2.60	-0.01	0.83
Denmark						
1990-98	1.79	0.16	0.40	0.26	-0.01	0.04
1995-98	2.34	0.20	0.75	1.54	0.08	0.39
France						
1990-98	1.26	0.24	0.23	0.11	-0.08	0.10
1995-98	1.84	0.35	0.41	0.58	-0.02	0.18
Germany						
1991-97	1.09	-0.05	0.54	-0.64	-0.27	0.07
1994-97	1.73	0.00	0.76	-0.55	-0.19	0.02
Italy						
1990-98	1.35	0.09	0.57	-0.21	-0.03	0.09
1995-98	1.46	0.09	0.68	0.37	0.01	0.28
United States						
1990-98	3.15	0.42	1.11	1.48	-0.02	0.52
1995-98	4.60	0.69	1.69	2.05	0.04	0.83

Source: ICT database (see appendix B).

The Contribution of the ICT Producing and the ICT Using Sectors to Labour Productivity Growth

Even though an acceleration of GDP growth, as noted above, might be a first sign of a positive effect emerging from the "new economy", only an acceleration in productivity growth will generate permanent growth effects from ICT. Table 6 provides a perspective on the acceleration or deceleration of labour productivity growth since the middle of the 1990s. For the total economy the productivity acceleration has clearly been much faster in the United States than in the European countries. The acceleration was especially strong in the American ICT producing industry, even though a similar acceleration was again observed for France. In contrast, productivity growth in ICT producing services in the US was much lower than in most European countries, and the accelerated less over time. A similar pattern can be observed for the ICT using sector even though the American productivity in ICT using services accelerated more than in ICT producing services.

Strikingly ICT using services in Germany are characterised by the fastest productivity growth of all six countries in the table. This appears closely related to the overall faster productivity growth of the German economy during 1990s which went together with a decline in employment (see tables 4 and 5). The development of the German ICT sector can therefore not be interpreted as a process of growth even not in ICT services.

Table 6: Acceleration or Deceleration of Labour Productivity Growth in ICT-producing and ICT-using sectors between 1995-98 and 1990-95

	Nether-lands	Denmark	France	Germany (a)	Italy	United States
Total economy						
1990-1995	1.2	2.0	1.1	2.3	1.9	1.2
1995-1998	0.8	0.9	1.3	2.3	1.1	2.0
ICT-producing industry						
1990-1995	7.3	6.2	8.6	5.0	3.9	9.6
1995-1998	3.3	4.3	16.2	9.7	0.0	17.1
ICT-producing services						
1990-1995	1.8	7.9	2.4	6.2	5.5	2.1
1995-1998	4.0	5.1	5.4	12.1	4.5	2.3
ICT-using industries						
1990-1995	5.8	4.9	5.7	4.7	3.4	4.1
1995-1998	2.7	2.1	7.5	5.4	1.7	8.1
ICT-using services						
1990-1995	0.8	2.2	0.4	2.2	2.4	1.7
1995-1998	2.2	1.4	1.0	4.3	1.3	3.1

(a) for Germany this refers to 1995-97 minus 1991-95.
Source: ICT database (see appendix B).

In the Netherlands both the ICT producing industry and the ICT using industry experienced a substantial slowdown in productivity growth. However, in the ICT producing and ICT using services in the Netherlands productivity growth accelerated substantially, and was (in contrast to Germany) very expansionary in terms of output and employment growth. The productivity deceleration in the Netherlands is primarily due to industries that do not intensively use ICT, such as construction, the real estate sector, several personal, community and social services and government. In Denmark the productivity deceleration developed more equally across all sectors of the economy.

To measure the exact contribution of the ICT-sector to overall labour productivity growth, one might use the "shift-share" method. This method implies that productivity for the total economy (P) can be perceived as the sum of the productivity contributions of individual industries (i) weighted with the labour share ($L_i/L=S_i$):

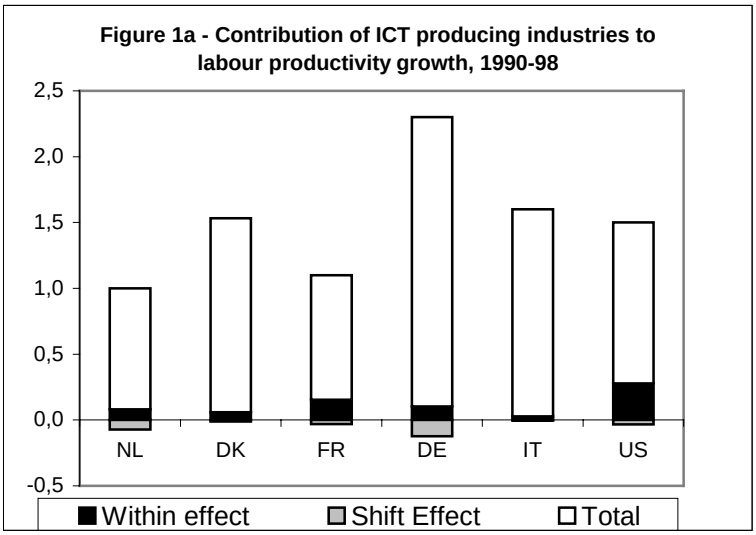
$$P = \frac{Y}{L} = \sum_{i=1}^{n}\left(\frac{Y_i}{L_i}\right)\left(\frac{L_i}{L}\right) = \sum_{i=1}^{n}\left(P_i S_i\right)$$

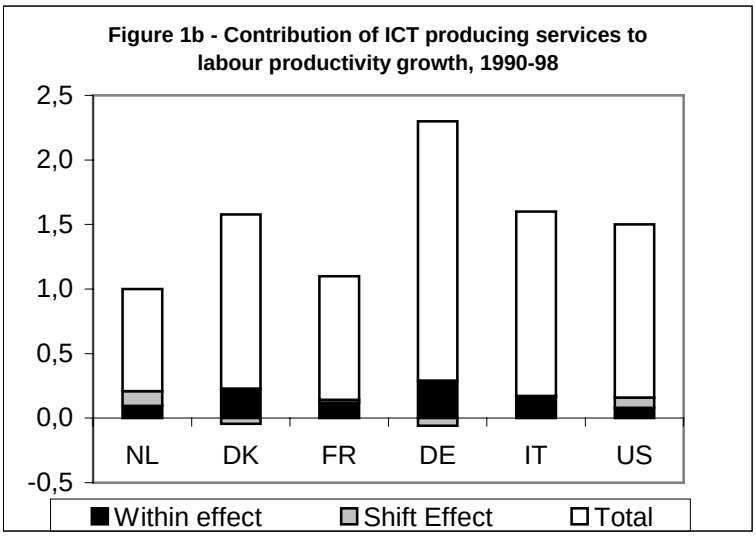
In a time perspective this equation can be rewritten as:

$$\Delta P_{(t)} = \sum_{i=1}^{n}\left(\Delta P_{i(t)} * S_{i(t-1)}\right) + \sum_{i=1}^{n}\left(P_{i(t-1)} * \Delta S_{i(t)}\right) + \sum_{k=1}^{n}\left(\Delta P_{i(t)} * \Delta S_{(t)}\right)$$

The first term on the right hand side of the equation is the "within-effect", which measures the contribution of growth *within* individual industries to the growth of the aggregate labour productivity. The labour shares for the previous year are used as weights. The second and third terms together

represent the contribution of a *shift* in shares of ICT producing or ICT using sectors on labour productivity growth. The second term, which may also be called the static effect, weights the changes in labour shares with the *level* of productivity in the previous year. A net shift in labour shares to industries with a high labour productivity level will have a positive static effect. The third term, which is called the dynamic effect, weights the changes in labour shares with the *growth* of labour productivity. A net shift in labour shares to industries with an above average labour productivity growth will lead to a positive contribution. An increased share of industries with a below average labour productivity growth will lead to a negative contribution to the aggregate.[10]





Figures 1a and 1b show the contributions of the within effect and the combined shift effects to labour productivity growth for ICT producing industries and ICT producing services respectively. Figure 1a shows that the "within-effect" in ICT producing industries is strongest in France and the United States. According to Figure 1b the within effect for ICT producing services is strongest for Germany.

[10] Similarly a decreasing share of industries with productivity growth below the average causes also a positive dynamic shift effect, whereas a decline in labour shares in industries with an above average productivity growth causes a negative dynamic effect.

However, it should be noted that this strong contribution is related to the fall in employment in Germany during the 1990s. The shift effects for the high-productivity ICT producing industries are mostly negative because of the decline in employment in this sector. In contrast, shift effects for the ICT producing services are mostly positive because of the increased importance of this sector which also has high productivity levels. Together the ICT producing industries and services in the European countries contributed for about 0.15-0.25 percentage points to labour productivity growth during the 1990s. In the United States the growth contribution of the ICT producing sector was double that of the European countries, namely about 0.4 percentage points.

The contribution of the ICT using sector to productivity growth (Figures 2a to 2c), which includes the contribution of ICT producers, is of course bigger but the differences between "within" and "shift" effects do not differ much from the pattern for the ICT producing sector. The total contribution of the ICT using sector to labour productivity growth (Figure 2c) is between 33 and 40 per cent for Denmark, France, Germany and Italy and more than two thirds for the Netherlands and the United States. This is a striking result as the latter two countries were also most successful in expanding employment in those sectors. In absolute terms the contribution of ICT to growth is less for the Netherlands than for the United States because of the lower aggregate productivity growth rate.

The most important conclusion from this section is that the acceleration of productivity growth in the United States is mainly due to the strong effect from ICT producing industries. This conclusion matches with observations from more detailed studies for the United States (Gordon, 1999; Jorgenson and Stiroh, 2000). It is striking that the differences between Europe and the United States are much smaller concerning the slower acceleration of productivity in ICT using industries, even though the US is still doing somewhat better here as well. However, there is much diversity within Europe. For example, the relative contribution of ICT to productivity growth is rather high in the Netherlands whereas the absolute contribution of ICT is highest in Germany. An important reason for such differences are growth differentials concerning employment in both countries.

Figure 2a - Contribution of ICT using industries to labour productivity growth, 1990-98

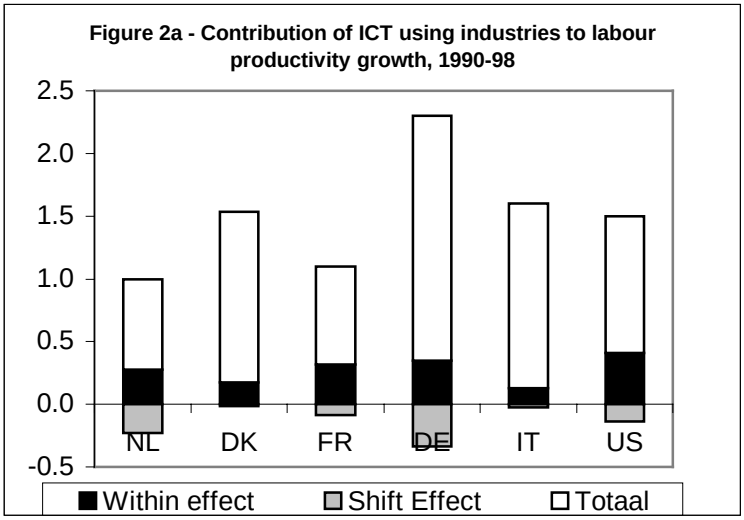


Figure 2b - Contribution of ICT using services to labour productivity growth, 1990-98

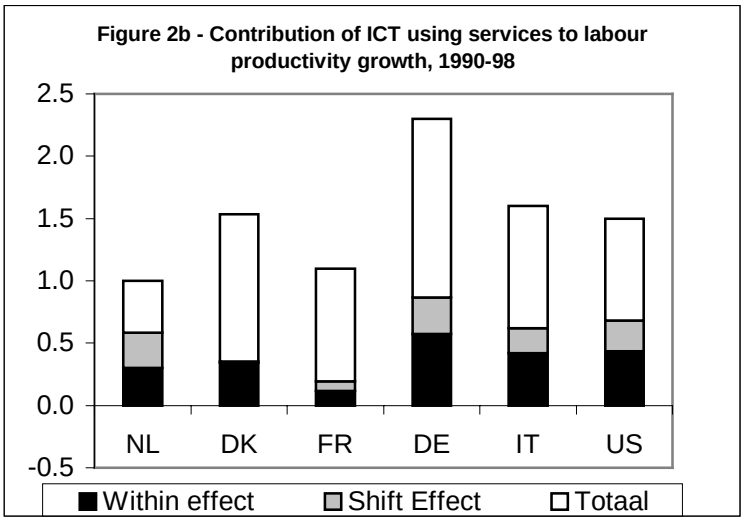
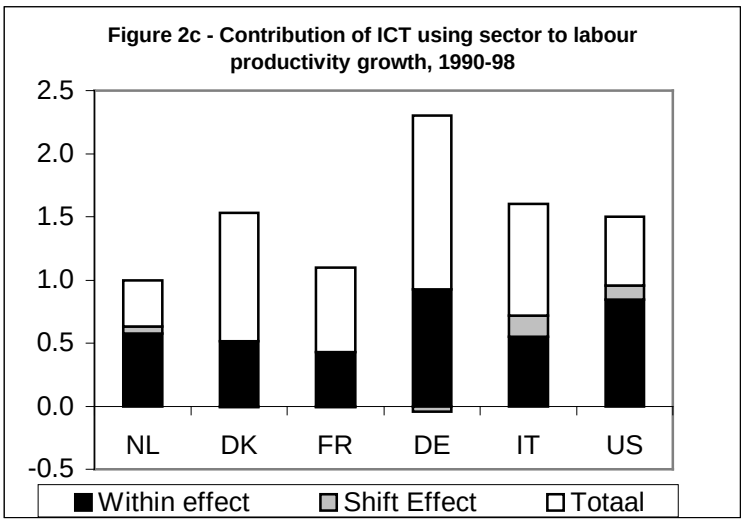


Figure 2c - Contribution of ICT using sector to labour productivity growth, 1990-98



4. The Importance of Measurement Problems

So far it was assumed that the real output and productivity estimates correctly reflect the actual situation. However, in the past few years there have been increasing concerns about whether the macroeconomic statistics correctly trace the changes in the information society or the "new economy". Griliches (1994) showed a striking difference between the acceleration of labour productivity growth in 'measurable' sectors of the American economy (agriculture, mining, manufacturing, transport and communication, and public utililities) and the slowdown in 'unmeasurable' sectors (like construction, trade, the financial sector, 'other' market services and government). Table 7 shows that this distinction is equally valid for other countries. The table also shows the rapid rise in the nominal share of 'difficult to measure' industries. For France and the Netherlands the nominal shares are in between the higher share in the United States and the lower shares in Germany and the United Kingdom.

Table 7: Labour Productivity Growth and Nominal Output Share of Measurable and Non-Measurable Sectors of the Economy, 1973-1998

	Netherlands		France		Germany		United Kingdom		United States	
	MS	UMS	MS	UMS	MS	UMS	MS	UMS	MS	UMS
GDP per hour worked (1973=100)										
1973	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1985	163.2	129.2	173.7	136.9	153.0	128.2	151.2	114.1	124.0	110.0
1990	177.6	135.4	214.5	144.8	176.8	146.4	185.6	119.3	191.6	112.2
1995	212.2	140.4	254.8	148.1	204.1	158.8	236.9	129.6	217.8	114.3
1998 (a)	231.2	143.7	276.1	147.5	224.5	166.1	246.3	134.3	251.9	123.7
Share of sector in current GDP (%)										
1973	44	56	46	54	50	50	45	55	45	55
1985	40	60	37	63	44	56	43	57	34	66
1998 (a)	31	69	31	69	35	65	34	66	28	72

MS = measurable sector (agriculture, mining, manufacturing, utilities, transport and communication)
UMS = unmeasurable sector (construction, wholesale and retail trade, finance, insurance and business services, other services and government)
(a) France and German figures are for 1997
Source: Groningen Growth and Development Centre Sectoral database.

Table 7 shows that all countries experienced a substantial productivity slowdown in the unmeasurable sectors of the economy since the mid 1980s. The slowdown was biggest in the United Kingdom and the United States and smallest in Germany. When focusing on the most recent period since 1990, France and the Netherlands appear at the bottom end. However, the longer time perspective in the table is informative as the United States was plagued by a similar slow growth during the 1980s.[11]

[11] The differences in productivity growth rates in services between European countries has been the subject of several studies. For example, CPB (1996) suggests that the slower productivity growth in the Netherlands compared to Germany is due to lower investment in Dutch services, and out-contracting of relatively simple service activities from industry (such as, security personnel, cleaners and catering services). The out-contracting in Germany is suggested to have been of less importance. McGuckin, Stiroh and van Ark (1997) emphasize the lack of structural reforms in Germany, in particular in the product market, as various service activities, for example in trade and personal services, did not expand much. More recently CPB analyzed in more detail the

There are various reasons for slower productivity growth in the 'unmeasurable' sector. As is consists mainly of services, the "cost-disease" hypothesis of Baumol applies strongly in this sector. However, the strong rise in the difference between the productivity growth rates in the measurable and unmeasurable sectors, observed by Griliches, suggests that measurement problems could be a cause as well. These measurement problems may, at least in part, be related to the increased use of ICT.

Van Ark (2000a) estimates the increase in measurement error related to the shift of labour towards the 'unmeasurable' sector in France, Germany, Netherlands, the United Kingdom and the United States. Using a shift-share method, the rise in the output share of those industries is multiplied by a constant measurement error of 2.4 per cent. This calculation suggests that the measurement error increased by 0.2 to 0.4 percentage point per year because of this shift during the period 1985-96 relative to the period 1960-73. Compared to the period 1973-1985 the rise in measurement error was between 0.1 and 0.2 percentage point per year.

To get a full view on the complex issue of the role of ICT in measurement problems of output, value added and productivity, one needs to make a clear distinction between the various sources of measurement problems caused by ICT. These can be divided into four categories, namely measurement problems with regard to the output in manufacturing (which is the major industry of the 'measurable' sector of the economy) and in services (which dominate the 'unmeasurable' sector) vis-à-vis measurement problems concerning the input of production factors and intermediate inputs in both sectors.[12] The diagram below presents a summary of the major problems in each quadrant as well as the most desirable and feasible solutions.

	Manufacturing	Services
Output	Primarily computers and other ICT, Solution primarily through use of hedonic price indices Feasible provided data availability	Most services with "customized" production, and non-market services (education, health, etc.) Solutions through detailed surveys on multiple dimension of output for each industry Difficult in methodological terms as well as in terms of data availability
Input	Primarily semiconductors Solution primarily through use of hedonic price indices Feasible given availability of data and use of capital-flow matrices	Primarily ICT input Solution through use of real input series adjusted with hedonic price deflators Feasible provided availability of capital-flow matrices

For manufacturing output the problems are still relatively simple. The nominal output and prices of industrial products are usually easy to measure. The measurement problem in this quadrant can therefore be roughly reduced to measuring ICT output in constant prices.[13] For the construction of

slow productivity growth in Dutch business services which was suggested to have been caused by lack of competition (van der Wiel, 1999).

[12] A similar analysis was applied by Baily and Gordon (1988) which led them to conclude that the measurement error in relation to the increased use of computers was a minor explanation of the productivity slowdown in the United States during the 1980s. However, the use of computers has of course strongly increased since the 1980s.

[13] Except for ICT these deflation problems also apply to some other industrial products, such as pharmaceutical products, large equipment and some durable consumer goods.

price indices to convert output series from current to constant prices, European statistical offices mostly use methods that compare prices of identical products in subsequent periods. Such a matched-model method is difficult to apply for products like computers (and other ICT goods) of which the technical characteristics change very rapidly. Hence it is increasingly difficult to adjust for quality adjustments in the price series. The alternative is to use hedonic price indices, which relates the prices of each good to changes in selected characteristics of the good. In the case of a personal computer such characteristics involve, for example, the type of processor, memory capacity, disk drives, CD-rom stations, etc.. (Triplett, 1989). The constant quality index that results from this procedure is then used to adjust the price index for computers. Since 1986 this method is used in the US National Income and Product Accounts (NIPA) and more recently also in Canada, France and Sweden.

Table 8: Labour Productivity Growth in ICT Producing Industry, 1990-1998

	Own national deflator (1990=100)	Labour productivity growth 1990-1998 (annual)	
		with own deflator	with US deflator
Netherlands	87.9	5.8	9.9
Denmark	106.2	5.5	12.3
France	57.1	11.4	9.7
Germany (a)	93.8	6.5	10.8
Italy	101.4	2.4	8.3
United States	64.6	12.3	12.3

(a) 1997
Source: ICT database (appendix B)

Wyckoff (1995) showed that the large differences in computer deflators between countries were primarily due to methodological differences. By applying the US deflator for office and computing equipment to nominal output in other countries, Wyckoff observed an upward adjustment of productivity growth in that industry of between 5 and 20 per cent in other countries than the US. Table 8 replicates Wyckoff's method for the 1990s, and for a somewhat more widely defined group of ICT producing industries (see appendix A). The first column of the table shows the national price indices for ICT producing industries, which suggests a faster price decline for two countries (France and the USA) of the three countries that use a hedonic methodology.[14] By using the American hedonic price index for office and computer equipment, productivity growth in the ICT producing sector in Germany and the Netherlands is adjusted upwardly by about 35 per cent, and in Denmark and Italy by about 60 per cent. Even though Wyckoff's study focussed exclusively on office and computer equipment, a comparison of the present results with his outcome suggests an increase in measurement problems related to ICT output. However, it should be emphasized that the composition of output in the ICT producing sector can differ between countries. As the computer hardware production in the United States mainly consists of PCs and semiconductors, an adjustment of the European series with a US

[14] The outcome for Denmark, however, is surprising: even though Statistics Denmark uses the US hedonic price index for computers, the prices of other ICT products (such as radio and TV and medical equipment) increased considerably. The somewhat faster decline in the price index for the Netherlands in comparison to Germany and Italy is due to the fact that the Netherlands (as France and the USA) applies a chain index for the computation of output and price indices.

deflator may lead to an exaggeration of the adjustment. In Europe production of peripherals is more strongly represented. Moreover it is doubtful whether one can assume that the computer hardware producing industry in Europe is as competitive as in the United States, which implies again that the price decline in Europe would be overstated when using the US index (Daveri, 2000).

Except adjusting the deflator for computer output, it is also necessary to make an adjustment for the most important ICT inputs in industry. Triplett (1996) showed that between 1974 and 1994 the prices of semiconductors declined almost 3000 times compared to only 20 times for computers over the same period. As semiconductors account for between 15 and 45 per cent of input costs in the computer industry, much to almost all of the productivity increase in the computer industry can be traced to the productivity gains in the semiconductor industry. This implies that the output price decline in computers leads to an overstatement of real value added (as in Table 8) if no adjustment is made for inputs as well. It is therefore most desirable to make a comprehensive adjustments of output and input prices in the ICT producing industry. An input-output framework with capital flow matrices is the adequate way to quantify these effects.

In the service sector, measurement problems are perhaps easier to deal with for inputs than for output. The most important technological inputs in the service sector are ICT inputs. The share of computers and other high tech equipment (mainly communication equipment) in the US capital stock in market services was 10.5 per cent in 1996 (McGuckin and Stiroh, 2000a). For the Netherlands the share of ICT investment in total investment in market services increased from 12 to 23 per cent between 1986 and 1995. The share of ICT equipment in the capital stock in market services in the Netherlands was 12 per cent on average between 1991 and 1995 (CPB, 2000b). Given the understatement of computer output in the Netherlands of about 35 per cent, as calculated above, the rise of ICT capital in services would be understand by 4.2 procent (i.e., on average about 0.5 per cent per year) during the period 1990 to 1998. It should be noted, however, that the effects may differ highly between service industries. For example, as much as 20 per cent of the ICT capital stock in the United States was concentrated in business services alone (McGuckin and Stiroh, 2000a). These rough estimates can be strongly improved if capital flow matrices, which measure the flows of equipment between industries subdivided by asset type, would be available.[15]

The largest measurement problems, however, relate to the measurement of output in the service sector. The traditional methodology of splitting the change in output value into a quantity component and a price component is difficult to apply to many service activities, as no clear quantity component can be distinguished. As long as the price or cost developments are not too much affected by quality changes of the services, the traditional method would suffice at least to measure the change in real output. In many service industries information on inputs (such as wage figures) was used as a proxy for output. Amongst other reasons, however, the increased importance of ICT may have made it more difficult to adequately reflect quality changes when using of input indicators. ICT has contributed to the so-called multi-dimensionality of services, which means that the real output of a particular service cannot be identified with one exclusive quantity indicator (den Hertog, 2000). At this place only some examples can be given, so that the overall quantitative impact on the real output measures for services cannot yet

[15] In addition, no account has been taken here of the increased importance of software as an input (see, for example, Daveri, 2000)

be determined. Improved inventory management in the trade sector has made it possible to differentiate supply of goods in terms of time, place and type of product. The diversity of products supplied by the financial sector has strongly increased, and the application of ICT makes it possible to customize financial products or combinations of those products (like an insurance, an investment fund and a mortgage). Services in the public sector, such as health care, are also increasingly characterized by diversity and differentiation in time, place and type of treatment. Such quality changes do not only lead to upward adjustments of real output. For example, Triplett (1999) quotes evidence on the use of automatic teller machines (ATM) at US banks which shows that quality changes in the banking sector may be exaggerated. Whereas ATM transactions cost half that of human teller transactions, about twice as many ATM transactions occur for the same volume of money transfered. Hence all the increased quality of ATM transactions must come from greater customer convenience, which is difficult to measure because ATM services typically go uncharged. The same difficulty in assessing customer convenience arises from the greater availability of flights at lower cost to many destinations, but with more time spent at crowded airports, sitting in packed planes, etc..

It should be emphasized that statistical offices are doing much to improve measurement methods. The US Bureau of Labor Statistics (that is responsible for the development of price indices) and the Bureau of Economic Analysis (that produces the National Income and Product Accounts) have introduced various improvements in measurement methods (Dean, 1999; Gullickson and Harper, 1999, Landefeld and Fraumeni, 2000). In particular the introduction of hedonic price indices and more recently chain indices (the latter already being an established practice in some European countries, including France and the Netherlands) has had a strong upward effect on the US measures of real output growth. These continuous adjustments of US series are also one of the most important points of criticism on ad-hoc changes in measurement methods.

In a series of reports the statistical office of the European Union, Eurostat, evaluated measurement practices in various service activitities, such as financial services and public services, and ‘difficult to measure’ production of goods, such as computers and large equipment (Eurostat, 1998a, 1998b, 1999a, 1999b, 2000). These reports suggest that many of the desired adjustments put a large demand on data and therefore on the burden for companies to report and on financial resources to process the data. An important priority is therefore to develop statistical techniques that make improvements possible on the basis of relative small databases.

The most important conclusion to be taken from this section is that the measurement error at macroeconomic level tends to increase because of the greater share of ‘difficult to measure’ industries in the economy. Moreover, there are strong indications that within these industries, in particular in services, measurement errors get bigger because of the increased use of ICT. It also appears that the use of hedonic price indices, which is applied or experimented with by many statistical office, is a promising avenue to improve the measurement of real output and input of computers. The biggest problem area, however, remains the measurement of real output in many service industries. How much of this explains the observed differences in output and productivity growth between countries remains unclear for the time being.

5. Investment and Innovations of the ICT Sector

So far this paper has focused on the contributions to growth of ICT producing industries and ICT using industries without taking into account the impact of ICT investment on productivity. One reason is that that reliable and internationally comparable estimates of ICT investment and ICT capital goods are still not available. So far there are only a few international comparisons that make use of estimates of ICT investment data based on ICT expenditure information.

In a study for the G-7 Schreyer (2000) uses data on ICT expenditures (as used in Table 1 above) which he reworked to estimates of investment on the basis of a number of assumptions.[16] The nominal investment figures were converted to real measures by using the difference between the US (hedonic) price index for ICT goods compared to the index for other capital goods, which (after smoothing) is applied to the price index for non-ICT goods for each individual country. Using the perpetual inventory method, Schreyer then cumulated investments which were scrapped on the basis of an age-efficiency pattern that declines slowly in the early years of an ICT capital good's service life and rapidly at the end. The contribution to growth of the services from ICT capital is then computed using a growth accounting technique, as developed by Jorgenson and associates, using users costs as weights. According to Schreyer the contribution of ICT capital in the G-7 increased from on average 7 per cent in the 1980s to 14 per cent in the beginning of the 1990s. In terms of labour productivity this meant a rise of the ICT contribution to growth from 8 per cent in the 1980s to 12 per cent in the early 1990s. In particular for labour productivity growth, the US numbers were clearly higher than the average for the G-7: during the 1980s the ICT contribution to US labour productivity growth was 18 per cent which increased to 23 per cent during the 1990s.

A more recent study by Daveri (2000) replicated Schreyer's method for a larger group of OECD countries. Daveri made substantial changes to Schreyer's method in reworking ICT-expenditure to ICT-investment data, but he relied more heavily on US evidence. A step forward in Daveri's work is that he includes an estimate for software investment. Daveri's estimates of the ICT contribution to growth are therefore substantially higher than those of Schreyer. With software included the contribution of ICT capital to GDP growth in OECD countries varies from between 0.23 and 0.66 percentage point during the period 1991-97. In terms of the percentage contribution to growth this implies an average contribution of 23 per cent.[17] Australia, Canada, the Netherlands, the United Kingdom and the United States are in the leading group of countries.

At national level similar studies were carried out for the United States and the Netherlands with actual investment data instead of reworked expenditure data. As mentioned in Section 4, CPB (2000b) finds that the share of ICT goods in the capital stock in the Netherlands is hardly lower than in the United States. In 1995 the share of ICT in the total capital stock of the market sector was about 6¾ per cent for the Netherlands compared to 7.5 per cent for the United States. The contribution of ICT capital to labour productivity growth in the Netherlands was somewhat lower than in the United States (namely

[16] The expenditure data on IT hardware were equalled to investment by assuming that the expenditure by consumers (which are included in the figures) was offset by the expenditures by unincorporated enterprises (which were not included). Using US evidence, Schreyer assumed that 30 per cent of expenditure on telecommunication was investment.

17 per cent in the Netherlands against 23 per cent in the United States during the early 1990s) but considerably higher than for other European countries in Schreyer's sample. For the second half of the 1990s (1995-1999) CPB shows a slight decline in the ICT contribution to labour productivity growth to about 15 per cent. However, given the moderate acceleration in labour productivity growth for the total economy in the Netherlands, the contribution in absolute terms remains the same (see Table 9). The CPB study also made a distinction between the contribution of ICT capital to labour productivity growth in industry and in market services, showing a much larger contribution for the latter than the former. This is primarily because of the much slower growth rate of labour productivity in market services. In absolute terms ICT does not generate much more productivity growth in services than in industry. Within market services there is a big difference between ICT producing services and other services. Strikingly the contribution of ICT capital to productivity growth in ICT services is negative in the most recent period. This, however, is not necessarily a negative sign as this implies the growth contribution of total factor productivity in the ICT producing services has increased.

Table 9: Contribution of ICT Capital to Labour Productivity Growth in the Netherlands, 1980-1999

	Market Sector	Industry	Market Services	ICT services	Other market Services
	labour productivity growth rates (annual average, %)				
1980-90	2.7	3.7	1.6		
1991-95	1.2	3.4	0.4	1.8	0.3
1996-99	1.3	2.5	1.5	4.0	0.8
	%-point contribution of ICT capital				
1980-90	0.1	0.1	0.1		
1991-95	0.2	0.1	0.2	1.0	0.25
1996-99	0.2	0.2	0.3	-1.0	0.25
	%-contribution to labour productivity growth				
1980-90	3	2	6		
1991-95	17	3	50	57	100
1996-99	15	8	20	-25	33

Source: CPB (2000b), Table 3.3 and p. 28

For the United States most studies were carried out at an aggregate level, including Oliner and Sichel (1994, 2000), Sichel (1999) and the Council of Economic Advisers (2000). The studies by Stiroh (1998) and Jorgenson and Stiroh (1999, 2000) are characterized by a more detailed analysis at industry level. Jorgenson and Stiroh (2000) distinguish 37 industries, and 59 types of investment as well as 13 types of durable consumer goods, land and inventories. For investment four types of ICT capital goods are distinguished, namely computers, communication equipment, software and consumer expenditures on computers and software.[18] The latter study shows that the contribution of these four ICT categories to real output growth in the market sector increased rapidly from 12 per cent during the period 1974-90 to about 20 per cent during the 1990s. Stiroh (1998) makes a distinction between computer producing

[17] Without software the contribution is about 17 per cent.

and computer using sectors, showing that the contribution of computers in the computer producing industry was fairly strong during the 1980s. However, computers in the computer using industries were primarily used as substitution for other capital goods without significantly contributing to an acceleration in total factor productivity growth. Unfortunately the data in Stiroh's study run only up to 1991. Jorgenson and Stiroh (2000) make no calculations of the contribution of ICT capital to productivity within each industry. They show that the contribution of ICT producing industries to TFP growth was about 60 per cent during the 1990s, while this sector accounts for only a few percentage points of total output. Strikingly the contribution of other industries than the ICT producing sector accelerated during the second half of the 1990s. This might indicate that ICT using industries also generate more TFP growth, but more research is required to substantiate this observation.

The analysis above on the basis of growth accounts assumes that the contribution of ICT capital to growth is weighted with returns based on the share of ICT capital in total factor income. This does not necessarily have to be the case if one assumes that ICT creates external effects. These external effects are not excluded from the studies dealt with above, but are allocated to a stronger contribution of total factor productivity growth instead of capital itself. Micro-oriented studies, which are based on data for individual firms obtained from surveys or longitudinal analysis of statistical information, typically find stronger effects of computer capital on output growth than of other (non-ICT) capital goods. An extensive discussion of the results from micro studies is beyond the scope of this paper.[19] Some general remarks, which are focused on the question to what extent an inconsistency exists between the results from micro and macro studies on the impact of ICT on growth, should therefore suffice. Firstly there are important differences between the output effect of different types of ICT-capital. The strongest effects are for personal computers (PC's) while other ICT-capital generates weaker effects (Lehr and Lichtenberg, 1999; Licht and Moch, 1999). The output elasticities of micro studies which use a broader definition of IT capital are usually smaller and closer to those of macro studies, in particular those with a disaggregation to industries.[20] Secondly micro studies are often focused on specific industries or groups of firms in which ICT intensive industries or relative large firms are overrepresented. Moreover it appears that firm specific and industry specific variables have a great impact on the effect of computer capital on performance. Brynjolfsson and Hitt (1995), for example, show that the positive effects of computers are reduced by half when firm specific factors are taken into consideration. Thirdly, and related to what was mentioned above, recent micro studies point in particular at the importance of organizational innovations which are needed to fully exploit the potentially positive effects from ICT investment ICT (Bresnahan, Brynjolfsson and Hitt, 2000).

Most importantly, however, is that the most recent macro studies which are discussed above, suggest stronger effects from ICT on output and productivity growth since the second half of the 1990s than before. This suggests that the positive effects of ICT might begin to diffuse across the economy. The observed acceleration of productivity growth in ICT using industries in some countries (including France, the Netherlands and the United States) are indicative of these trends.

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[18] Software and consumer expenditures on computers and software are not included in Schreyer (2000) and CPB (2000b).

[19] See Van Ark (2000a) for a more detailed review.

[20] McGuckin and Stiroh (2000b) show that effects are indeed weaker in studies that focus exclusive on the aggregate economy because of the strong influence of aggregation effects.

6. Conclusions and Further Considerations

This paper aimed to document the contribution of production and use of information and communication technology (ICT) to economic growth. An important goal was to analyse to what extent differences in ICT production and ICT use accounted for the decelerating productivity growth in countries in the European Union compared to the United States during the 1990s. This study confirmed the existing view that an important part of the productivity growth acceleration in the United States could be ascribed to ICT producing industries. The effects of ICT use on growth appear smaller between countries but also more subtle. For example, the effects of computer using services on growth tend to be smaller between Europe and the USA than for computer using industries. Even though the contribution of the ICT using sector to productivity growth came closer to the estimates for the United States, many European countries have not succeeded to generate positive employment effects through intensive ICT use.

This paper suggests that there are clear indications that the growth contribution of ICT to growth increased during the second half of the 1990s. This may be related to the fact that the characteristics of ICT as a general purpose technology are becoming increasingly strong. These characteristics include the great impact of ICT across the economy, the broad range of applications in production processes, the complementarity of ICT with other technological developments and innovations, and the evolutionary nature of the technology so that new applications and cost reductions are realised on a continuous basis (Bresnahan and Trajtenberg, 1995; Helpman, 1998; CPB 2000a). These characteristics also explain why the effects of ICT on productivity occur with a certain delay (David, 1990). This means that the present productivity advantage in the USA over the European countries could erode when European firms make a larger and more effective use of ICT. The renewal of the old economy is then reality and the term ‘new economy’ can then be stalled until a new major technological breakthrough occurs. However, lack of structural reforms in product and labour reforms may still stand in the way of making such a leap forward in Europe possible.

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Appendix A – Classification of ICT producing and ICT using industries

Appendix Table 1 – Classification of ICT producing, ICT using and other sectors of the Economy

ISIC Rev. 3	**ICT-producing industries**
30	Office, Accounting and Computing Machinery
313	Insulated Wire and Cable
32	Radio, Television and Communication Equipment
331	Medical Appl. & Instruments & Appl. for Measurement, etc.
64	Post and Telecommunications
72	Computer and Related Services

ISIC Rev. 3	**ICT-using industries**	Netherlands		**United States** according to	
		IT investment as % of production value	IT capital as % of total IT capital	McGuckin and Stiroh (1999)	NSF (2000) Table 9.3
22	Publishing	0.9	3.0	x	
24	Chemicals and Chemical Products	0.1	3.1		x
30	Office, Accounting and Computing Machinery	0.6	2.2	x	x
31	Electrical Machinery, Apparatus, nec	0.3	a)	x	x
32	Radio, Television and Communication Equipment	1.0	a)	x	x
33	Medical, Precision and Optical Instruments	0.4	b)	x	x
51	Wholesale Trade	0.7	11.0	x	x
64	Post and Telecommunications	1.2	8.0 c)		x
65	Financial Intermediation	4.4	17.4	x	x
66	Insurance and Pension Funding	1.2	4.2	x	x
67	Activities Related to Financial Intermediation	1.6	1.8	x	
71	Renting of Machinery and Equipment	1.0	0.7		
72	Computer and Related Services	2.6	9.0		x
73	Research and Development	0.8	12.2		
741-743	Other Business Services	b)	b)	x	x
	All ICT-using industries	1.2	72.6		
	Total Economy	0.6	100.0		

a) included in Office, Accounting and Computing Machinery
b) not shown separately
c) included in Transportation
Source: based on CPB (2000b)

Appendix B – ICT Database

The database for this paper is primarily based on the renewed "STAN industrial database" of the OECD, which is still under development and as yet not published. In most cases the data in STAN are based of the new system of national accounts introduced during the 1990s, i.e. the System of National Accounts 1993 or the European System of Accounts 1995. For the Netherlands, for which no STAN data were available as yet, use is made of the *Nationale Rekeningen 1997* (1990-1995) to which the trends from the *Nationale Rekeningen 1998* (1995-1998) were linked (hence the levels of GDP in the Netherlands were still based on the old system of national accounts). In some cases, in particular for the classifying of ICT producing industries, the STAN were too aggregated. For example, to splitt off insulated wire and cable and medical appliances and instruments shares on production, value added and employment were obtained from OECD *Industrial Structure Statistics* (1999 edition). This source was also used to distinguish between paper, etc. (not part of the ICT using sector) and printing and publishing (which is part of ICT the using sector). The estimates for wholesale trade (part of the ICT using sector) and retail trade (not part of the ICT using sector) are split off with the help of OECD *Statistics on Services* (2000 edition). This source, together with Eurostat, *Services in Europe* (1999), was also used to distinguish between business services that were or were not part of the ICT-using sector. In a number of cases business services could not be correctly split into these two parts because of lack of data: in the case of Denmark and Germany a 50-% split was therefore used. In some cases national accounts for the individual countries were used to extend trends or to obtain a further disaggregation. The figures on value added in current prices are expressed in basis prices, and the series on real value added are linked to the price level of 1995. Employment includes self employed persons. An adjustment for working hours per person appeared not possible at this stage.

Appendix C – Results from shift-share analyse of ICT producing and ICT-using industries

Appendix Table C1: Growth Contribution of ICT Producing Sectors to Growth of Real Value Added per Person Employed, 1990-1998

	Annual Growth Rate Labour Productivity of Sector	%-point contribution to productivity growth of total economy					Growth Rate Labour Productivity Total Economy
		Intra-branch effect	Shift Effect			Total contru-bution	
			Static	Dynamic	Total		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Industry-producing sector							
Netherlands	4.1	0.18	0.04	0.00	0.04	0.22	1.0
Denmark	6.5	18.9	-3.2	-0.4	-3.6	15.3	1.5
France	5.7	0.28	0.00	0.00	-0.01	0.27	1.1
Germany (a)	8.4	0.39	-0.17	-0.01	-0.18	0.21	2.3
Italy	4.5	0.20	0.00	0.00	0.00	0.19	1.6
United States	5.8	0.36	0.05	0.00	0.05	0.41	1.5
ICT-producing industry							
Netherlands	5.8	0.08	-0.07	-0.01	-0.07	0.01	1.0
Denmark	5.5	3.9	-0.6	-0.1	-0.7	3.2	1.5
France	11.4	0.15	-0.03	0.00	-0.03	0.12	1.1
Germany (a)	6.5	0.10	-0.12	-0.01	-0.12	-0.02	2.3
Italy	2.4	0.03	0.00	0.00	0.00	0.02	1.6
United States	12.3	0.28	-0.03	0.00	-0.03	0.25	1.5
ICT-producing services							
Netherlands	2.6	0.10	0.11	0.00	0.11	0.21	1.0
Denemark	6.8	15.0	-2.6	-0.4	-2.9	12.1	1.5
France	3.5	0.12	0.02	0.00	0.02	0.14	1.1
Germany (a)	8.1	0.29	-0.06	-0.01	-0.06	0.23	2.3
Italy	5.2	0.17	0.00	0.00	0.00	0.17	1.6
United States	2.2	0.08	0.08	0.00	0.08	0.16	1.5

(a) For Germany for 1991 and 1997
Source: ICT database (see appendix B).

Appendix Table C2: Growth Contribution of ICT-Using Sectors to Growth of Real Value Added per Person Employed, 1990-1998

	Annual Growth Rate Labour Productivity	%-point contribution to Productivity Growth Total Economy					Growth Rate Labour Productivity Total Economy
		Intra-branch Effect	Shift Effect			Total Contri-bution	
			Static	Dynamic	Total		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ICT-using industry							
Netherlands	4.6	0.28	-0.22	-0.01	-0.23	0.05	1.0
Denmark	3.9	0.17	-0.02	0.00	-0.02	0.16	1.5
France	6.4	0.32	-0.08	-0.01	-0.09	0.23	1.1
Germany (a)	5.0	0.35	-0.32	-0.02	-0.34	0.01	2.3
Italy	2.8	0.13	-0.03	0.00	-0.03	0.10	1.6
United States	5.6	0.41	-0.13	-0.01	-0.14	0.27	1.5
ICT-using services							
Netherlands	1.3	0.30	0.28	0.00	0.28	0.58	1.0
Denmark	1.9	0.34	0.01	0.00	0.01	0.35	1.5
France	0.6	0.11	0.08	0.00	0.08	0.20	1.1
Germany (a)	2.9	0.58	0.29	0.01	0.29	0.87	2.3
Italy	2.0	0.42	0.20	0.00	0.20	0.62	1.6
United States	2.2	0.44	0.24	0.01	0.25	0.68	1.5
Other industry							
Netherlands	2.5	0.28	-0.23	-0.01	-0.24	0.04	1.0
Denemarken	0.8	0.11	-0.12	0.00	-0.12	-0.01	1.5
France	2.9	0.38	-0.28	-0.01	-0.29	0.09	1.1
Germany (a)	3.2	0.55	-0.57	-0.02	-0.59	-0.04	2.3
Italy	2.1	0.35	-0.10	0.00	-0.11	0.25	1.6
United States	2.7	0.21	-0.12	0.00	-0.13	0.08	1.5
Other services							
Netherlands	0.4	0.18	0.25	0.00	0.25	0.43	1.0
Denemarken	1.0	0.54	0.30	0.00	0.30	0.85	1.5
France	0.1	0.07	0.54	0.00	0.54	0.62	1.1
Germany (a)	0.9	0.43	0.84	0.01	0.85	1.28	2.3
Italy	0.4	0.24	0.32	0.00	0.32	0.56	1.6
United States	1.0	0.41	0.02	0.00	0.02	0.42	1.5

(a) For Germany for 1991 and 1997

(b) "Other" refers to industries that are not part of the ICT-producing and ICT-using sector in industry and services (see appendix table 1). Other industries outside industry and services (agriculture, mining and construction) are not included. These represent the difference between the contributions of ICT-using industries and "Other industries" and the labour productivity growth rate for the total economy

Source: ICT database (see appendix B).